

POWER PLANT RELIABILITY

Testimony of Shahab Khoshmashrab and Steve Baker

INTRODUCTION

In this analysis, Energy Commission staff addresses the reliability issues of the project to determine if the power plant is likely to be built in accordance with typical industry norms for reliability of power generation. Staff uses this level of reliability as a benchmark because it ensures that the resulting project would likely not degrade the overall reliability of the electric system it serves (see **Setting** below).

The scope of this power plant reliability analysis covers:

- equipment availability;
- plant maintainability;
- fuel and water availability; and
- power plant reliability in relation to natural hazards.

Staff examined the project design criteria to determine if the project is likely to be built in accordance with typical industry norms for reliability of power generation. While East Altamont Energy Center, LLC, (applicant) has predicted a 92 to 98 percent availability for the East Altamont Energy Center (EAEC) (see below), staff uses the benchmark identified above, rather than the applicant's projection, to evaluate the project's reliability.

LAWS, ORDINANCES, REGULATIONS AND STANDARDS (LORS)

Presently, there are no laws, ordinances, regulations or standards (LORS) that establish either power plant reliability criteria or procedures for attaining reliable operation. However, the commission must make findings as to the manner in which the project is to be designed, sited and operated to ensure safe and reliable operation (Cal. Code Regs., tit. 20, § 1752(c)). Staff takes the approach that a project's reliability is acceptable if it does not degrade the reliability of the utility system to which it is connected. This is likely the case if the project exhibits reliability at least equal to that of other power plants on that system (see **Setting** below).

SETTING

In the regulated monopoly electric industry of past decades, the utility companies assured overall system reliability, in part, by maintaining a "reserve margin." This amounted to having on call, at all times, sufficient generating capacity, in the form of standby power plants, to quickly handle unexpected outages of generating or transmission facilities. The utilities generally maintained a seven- to ten-percent reserve margin, meaning that sufficient capacity was on call to quickly replace from seven to ten percent of total system resources. This margin proved adequate, in part because of the reliability of the power plants that constituted the system.

Now, in the newly restructured competitive electric power industry, the responsibility for maintaining system reliability falls largely to the California Independent System Operator (CalSO), an entity that purchases, dispatches and sells electric power throughout the state. How CalSO will ensure system reliability is still being determined; protocols are being developed and put in place that will, it is anticipated, allow sufficient reliability to be maintained under the competitive market system. “Must-run” power purchase agreements and “participating generator” agreements are two mechanisms being employed to ensure an adequate supply of reliable power (Mavis 1998, pers. comm.).

The CalSO also requires those power plants selling ancillary services, as well as those holding reliability must-run contracts, to fulfill certain requirements, including:

- filing periodic reports on plant reliability;
- reporting all outages and their causes; and
- scheduling all planned maintenance outages with the CalSO (Detmers 1999, pers. comm.).

The CalSO’s mechanisms to ensure adequate power plant reliability apparently have been devised under the assumption that the individual power plants that compete to sell power into the system will each exhibit a level of reliability similar to that of power plants of past decades. However, there is cause to believe that, under free market competition, financial pressures on power plant owners to minimize capital outlays and maintenance expenditures may act to reduce the reliability of many power plants, both existing and newly constructed (McGraw-Hill 1994). It is possible that, if significant numbers of power plants exhibit individual reliability sufficiently lower than this historical level, the assumptions used by CalSO to ensure system reliability will prove invalid, with potentially disappointing results. On November 29, 2001, the CalSO Board of Directors determined to pursue a program to establish and enforce power plant maintenance standards (McCorkle 2001).

Until the restructured competitive electric power system has undergone a shakeout period, and the effects of varying power plant reliability are thoroughly understood and compensated for, staff deems it wise to encourage power plant owners to continue to build and operate their projects to the level of reliability to which all in the industry are accustomed.

The applicant proposes to operate the 1,100 MW (nominal) EAEC, selling energy and capacity to the power market and via bilateral contracts (EAEC 2001a, AFC §§ 1.1, 2.2.2, 10.2.2, 10.3). The EAEC will operate as an 820 MW baseload power plant with an additional peaking capacity of up to 269 MW, achieved through the use of unusually large duct burners (EAEC 2001hh) (see **Power Plant Efficiency**). The project is expected to operate at an overall availability in the range of 92 to 98 percent (EAEC 2001a, AFC §§ 2.2.2, 2.2.16, 2.4.1, 10.2.2), and at a capacity factor, over the life of the plant, of 25 to 100 percent of base load (EAEC 2001a, AFC §§ 2.4.1, 10.2.2). The applicant envisions operating the plant up to 8,760 hours per year with the incremental peaking capacity operated for up to 5,080 hours per year (EAEC 2001a, AFC § 10.2.2).

ANALYSIS

The availability factor for a power plant is the percentage of the time that it is available to generate power; both planned and unplanned outages subtract from its availability. Measures of power plant reliability are based on its actual ability to generate power when it is considered available and are based on starting failures and unplanned, or forced, outages. For practical purposes, reliability can be considered a combination of these two industry measures, making a reliable power plant one that is available when called upon to operate. Throughout its intended 30-year life (EAEC 2001a, AFC § 10.2.2), the EAEC will be expected to perform reliably. Power plant systems must be able to operate for extended periods without shutting down for maintenance or repairs. Achieving this reliability is accomplished by ensuring adequate levels of equipment availability, plant maintainability with scheduled maintenance outages, fuel and water availability, and resistance to natural hazards. Staff examines these factors for the project and compares them to industry norms. If they compare favorably, staff can conclude that the EAEC will be as reliable as other power plants on the electric system, and will therefore not degrade system reliability.

EQUIPMENT AVAILABILITY

Equipment availability will be ensured by use of appropriate quality assurance/ quality control (QA/QC) programs during design, procurement, construction and operation of the plant and by providing for adequate maintenance and repair of the equipment and systems (discussed below).

Quality Control Program

The applicant describes a QA/QC program (EAEC 2001a, AFC § 2.4.5) typical of the power industry. Equipment will be purchased from qualified suppliers, based on technical and commercial evaluations. The project will maintain a record of documents for review and reference including vendor instruction manuals; design calculations and drawings; quality assurance reports; inspection and equipment testing; conformed construction drawings and records; procurement specifications; and purchase orders and correspondence. The project owner will perform receipt inspections, test components, and administer independent testing contracts. Staff expects implementation of this program to yield typical reliability of design and construction. To ensure such implementation, staff has proposed appropriate conditions of certification under the portion of this document entitled **Facility Design**.

PLANT MAINTAINABILITY

Equipment Redundancy

A generating facility called on to operate in baseload service for long periods of time must be capable of being maintained while operating. A typical approach for achieving this is to provide redundant examples of those pieces of equipment most likely to require service or repair.

The applicant plans to provide appropriate redundancy of function for the project (EAEC 2001a, AFC § 2.4.2). The fact that the project consists of three trains of gas turbine generators/HRSGs provides inherent reliability. Failure of a non-redundant component

of one train should not cause the other trains to fail, thus allowing the plant to continue to generate (at reduced output). Further, the plant's distributed control system (DCS) will be built with typical redundancy (EAEC 2001a, AFC § 2.4.2.2). Emergency DC and AC power systems will be supplied by redundant batteries, chargers and inverters (EAEC 2001a, AFC § 2.2.5.3). Other balance of plant equipment will be provided with redundant examples (EAEC 2001a, AFC § 2.4.2; EAEC 2001hh), thus:

- two 100-percent HRSG feed water pumps per HRSG;
- three 50-percent condensate pumps;
- two 50-percent circulating water pumps;
- two 100-percent closed-cycle cooling water pumps;
- two 100-percent closed-cycle cooling water heat exchangers; and
- three 50-percent demineralized water systems with redundant installed pumps.

The applicant proposes to construct the EAEC power generation facility in a three-on-one configuration (with only one condenser and one cooling system). (For a more detailed discussion of this configuration, see **Power Plant Efficiency**.) If the steam turbine generator should fail, steam from the HRSGs can be bypassed directly to the condenser, allowing the gas turbines to continue to operate, producing up to 540 MW. However, a single failure of the condenser or the cooling system would force the entire plant to shut down, resulting in the loss of up to 1,100 MW at maximum generation. In the Potrero Power Plant Unit 7 Project (00-AFC-4), the CalSO expressed concern that the 540 MW unit could be shut down by a single condenser or cooling system failure.

On the other hand, CalSO is not overly concerned with the EAEC project due to its remote location (Miller 2002). CalSO typically plans for a single system loss of 1,150 MW, their chief concern being a system stability problem from failure of a plant. This concern arises mainly where local area benefits are a question, as at Potrero in San Francisco, where the loss of only 500 MW from a single failure is a concern.

To minimize the likelihood of failure, the EAEC steam turbine will have two dual flow low pressure sections. Because of this, the turbine will have two surface condensers. The most common failure mode for the surface condensers is a tube leak, where circulating water leaks into the condensate, thus contaminating the condensate (EAEC 2001hh). To avoid the necessity of tripping the steam turbine because of a condenser leak, the applicant will utilize condensers with divided water boxes. This feature allows one-half of the condenser to be taken out of service to repair tube leaks while the other half continues to operate. The benefit of this design is that the steam turbine continues to operate, generating a large amount of its full-load output. Also, because the EAEC is a zero liquid discharge facility, the condensers will be constructed of titanium. The welded joints and superior corrosion resistance of the titanium condensers should result in fewer tube leaks than condensers fabricated of standard materials.

The circulating water piping will be concrete with welded steel joints. Thus, the potential for leaks in the circulating water piping will be extremely low.

The cooling tower for the EAEC will contain 19 cells. Provisions will be included to allow each cell to be individually isolated in the event of a fan, motor or gearbox failure (EAEC 2001hh). With 18 cells working, the cooling tower will be capable of operating at more than 95 percent of its design capacity. The cooling tower basin for the EAEC will be constructed such that approximately one-half of the basin can be taken out of service while the other half continues to operate. Typically, the cooling tower basin will be cleaned during plant outages. However, this feature will allow half the cooling tower to be taken out of service without tripping the steam turbine in the event that the basin needs to be cleaned between outages. With only half of the cooling tower in operation, the steam turbine will be capable of generating more than half of its maximum output (EAEC 2001hh).

The EAEC will use two 50-percent circulating water pumps. If one pump were to fail, the other pump would "run out" further on its curve, pumping much more than 50-percent of the total design flow, thus allowing the steam turbine to generate two thirds of its maximum output (EAEC 2001hh).

With the opportunity for continued operation in the face of equipment failure, staff believes that equipment redundancy would be sufficient for a project such as this.

Maintenance Program

The applicant proposes to establish a plant maintenance program typical of the industry (EAEC 2001a, AFC §§ 2.4.1, 2.4.5, 10.2.2). Equipment manufacturers provide maintenance recommendations with their products; the applicant will base its maintenance program on these recommendations. For example, each gas turbine will be scheduled for a week to 10 days per year off-line (at times of low electricity demand) in order to perform annual inspections and cleaning. Every third year, each gas turbine will undergo a hot gas path inspection lasting up to three weeks. Every sixth year, each gas turbine will undergo a major maintenance turnaround that typically lasts at least four weeks. The program will encompass preventive and predictive maintenance techniques. Maintenance outages will be planned for periods of low electricity demand. In light of these plans, staff expects that the project will be adequately maintained to ensure acceptable reliability.

FUEL AND WATER AVAILABILITY

For any power plant, the long-term availability of fuel and of water for cooling or process use is necessary to ensure reliability. The need for reliable sources of fuel and water is obvious; lacking long-term availability of either source, the service life of the plant may be curtailed, threatening the supply of power as well as the economic viability of the plant.

Fuel Availability

The EAEC will burn natural gas from the Pacific Gas and Electric Company (PG&E) system. Gas will be transmitted to the plant, via a new 20 inch diameter pipeline connection to PG&E's Line 401 (EAEC 2001a, AFC §§ 1.1, 1.3.2, 2.1, 2.4.3, 6.0, 10.2.1; EAEC 2002n, p. 2). The PG&E natural gas system represents a resource of considerable capacity. This system offers access to adequate supplies of gas (EAEC

2001a, AFC § 10.2.1). Staff agrees with the applicant's prediction that there will be adequate natural gas supply and pipeline capacity to meet the project's needs.

Water Supply Reliability

The EAEC will obtain water for plant cooling and process makeup via the Byron Bethany Irrigation District (BBID) from two sources of water, surface water and recycled water. During the initial years of plant operation, raw water will be provided by BBID. The applicant states that as the community of Mountain House, a newly approved town near the project site, is developed and recycled water becomes available, recycled water will supplement raw water, resulting in the reduction in raw water use by up to 62 percent by year 2024 (EAEC 2001a, AFC §§ 1.1, 1.5.2, 7.0, 8.14, 10.2.2, Table 7-1B). Domestic water will be provided by treating BBID water. For further discussion of water supply, see that portion of this document entitled **Water Resources**.

POWER PLANT RELIABILITY IN RELATION TO NATURAL HAZARDS

Natural forces can threaten the reliable operation of a power plant. High winds, tsunamis (tidal waves) and seiches (waves in inland bodies of water) will not likely represent a hazard for this project, but flooding and seismic shaking (earthquake) present credible threats to reliable operation.

Flooding

The site is essentially flat with an elevation of approximately 40 feet above mean sea level and is not within either the 100- or 500-year flood plain. The project area is protected from flooding by levees and drainage channels to the west and north (EAEC §§ 2.3.1, 8.14.1.3). Staff believes that there are no special concerns with the power plant functional reliability due to flooding events. For further discussion, see that portion of this document entitled **Water Resources**.

Seismic Shaking

The site lies within Seismic Zone 4 (EAEC 2001a, AFC § 2.3.1); see the portion of this document entitled **Geology and Paleontology**. The project will be designed and constructed to the latest appropriate LORS (EAEC 2001a, AFC § 10.4, Appendix 10B2). Compliance with current LORS applicable to seismic design represents an upgrading of performance during seismic shaking compared to older facilities, due to the fact that these LORS have been periodically and continually upgraded. By virtue of being built to the latest seismic design LORS, this project will likely perform at least as well as, and perhaps better than, existing plants in the electric power system. Staff has proposed conditions of certification to ensure this; see the portion of this document entitled **Facility Design**. In light of the historical performance of California power plants and the electrical system in seismic events, staff believes there is no real concern that power plant reliability will affect the electric system's reliability due to seismic events.

COMPARISON WITH EXISTING FACILITIES

Industry statistics for availability factors (as well as many other related reliability data) are kept by the North American Electric Reliability Council (NERC). NERC continually polls utility companies throughout the North American continent on project reliability data through its Generating Availability Data System (GADS), and periodically summarizes and publishes the statistics on the Internet (<http://www.nerc.com>). NERC

reports the following summary generating unit statistics for the years 1994 through 1998 (NERC 1999):

For Combined Cycle units (All MW sizes)

Availability Factor = 91.49 percent

The General Electric Frame 7F gas turbines that will be employed in the project have been on the market for several years now, and can be expected to exhibit typically high availability. While the 7FB is new, it represents a minor improvement over the 7FA, which has already proven itself in actual service. General Electric can be expected to quickly deal with any Frame 7FB reliability issues that may occur. In light of this, the applicant's prediction of an annual availability factor in the 92 to 98 percent range (EAEC 2001a, AFC §§ 2.2.2, 2.2.16) appears reasonable compared to the NERC figure for similar plants throughout North America (see above). In fact, these new, large machines can well be expected to outperform the fleet of various (mostly older and smaller) gas turbines that make up the NERC statistics. Further, since the plant will consist of three parallel gas turbine generating trains, much maintenance can be scheduled during those times of year when the full plant output is not required to meet market demand, typical of industry standard maintenance procedures. The applicant's estimate of plant availability therefore appears realistic. The stated procedures for assuring design, procurement and construction of a reliable power plant appear to be in keeping with industry norms.

Note that the applicant proposes to take all customary measures to maximize the reliability of the condenser and cooling system, including the incorporation of dual steam condensers with divided water boxes, titanium condenser tubing, and cooling tower and circulating water system designs that minimize the chances of a failure causing plant shutdown (EAEC 2001hh).

Energy Commission staff believes the EAEC can be expected to be adequately reliable, in line with industry norms.

Dry Cooling vs. Wet Cooling

The applicant proposes to employ a wet cooling system for the EAEC, and has provided an analysis of an alternative dry cooling system. The applicant described how the use of dry cooling on hot summer days reduces the cooling effect, causing a reduction of up to 46.4 MW (plant-wide) in the EAEC's power output (EAEC 2001p). This is a four percent drop in the overall power plant output. Furthermore, if temperatures rise too high, steam is no longer condensed rapidly enough, and plant output must be reduced, or the plant may have to be shut down entirely. This decreases plant availability on very hot days, when power is most needed. However, because there are only a few very hot summer days per year at the project site, the possible impacts of plant shutdown due to high temperatures would be minimal. Staff believes the electric system's reliability would not be affected significantly by the slight change in power output, or the remote possibility of plant shutdown, due to very high temperatures during hot summer days.

The use of dry cooling would reduce the plant's overall water consumption by approximately 98 percent (EAEC 2001p), limiting water usage to boiler makeup (to

replenish losses resulting from blowdown and power augmentation), combustion turbine inlet air fogging, and potable and service water needs. Using wet cooling would require a vast amount of water, which in turn requires reliable water supply resources that can provide such capacity. (Water availability is addressed in the portion of this document entitled **Water Resources**.) From a reliability standpoint, staff regards the use of dry cooling as a justifiable modification. (Note that the applicant estimates potential revenue losses approaching \$10 million per year if dry cooling is employed (EAEC 2002a). Staff does not purport to address the economics of a switch to dry cooling.)

FACILITY CLOSURE

Closure of the facility, whether planned or unplanned, cannot impact power plant reliability. Reliability impacts on the electric system from facility closure, should there be any, are dealt with in the portion of this document entitled **Transmission System Engineering**.

CONCLUSIONS AND RECOMMENDATION

The applicant predicts an equivalent availability factor in the 92 to 98 percent range, which staff believes is achievable in light of the industry norm of 91.5 percent for this type of plant. CalSO has stated that it can plan around a plant failure of up to 1,150 MW (Miller 2002). The applicant proposes to take all customary measures to maximize the reliability of the condenser and cooling system in order to minimize the possibility of total plant failure (EAEC 2001hh). Therefore, staff is not overly concerned about a single failure of the condenser or the cooling system.

Staff concludes that the plant will be built and operated in a manner consistent with industry norms for reliable operation. This should provide an adequate level of reliability. No Conditions of Certification are proposed.

REFERENCES

Detmers, Jim. 1999. Director of Maintenance and Reliability, California Independent System Operator. Interview with Steve Baker (California Energy Commission), July 13, 1999.

EAEC (East Altamont Energy Center) 2001a. Application for Certification, Volume 1 & Appendices, East Altamont Energy Center (01-AFC-4). Submitted to the California Energy Commission on March 29, 2001.

EAEC (East Altamont Energy Center) 2001p. Responses to Data Request Set #2. Submitted to California Energy Commission on August 17, 2001.

EAEC (East Altamont Energy Center) 2001 hh. East Altamont Energy Center Informal Data Requests and Responses Set #3 (01-AFC-4), dated November 21, 2001.

EAEC (East Altamont Energy Center) 2002 a. East Altamont Energy Center PSA Comments, Set #1 (01-AFC-4), dated January 14, 2002.

EAEC (California Energy Center) 2002 n. Supplement C to the East Altamont Energy Center AFC. Dated February 6, 2002 and docketed February 6, 2002.

Mavis, Steve. 1998. Transmission Planner, California Independent System Operator. Telephone conversation with Steve Baker (California Energy Commission), January 23, 1998.

McCorkle, Stephanie. 2001. California Independent System Operator News Release, November 29, 2001.

McGraw-Hill (McGraw-Hill Energy Information Services Group). 1994. *Operational Experience in Competitive Electric Generation, an Executive Report*, 1994.

Miller, Jeff. 2002. California Independent System Operator. Telephone conversation with Steve Baker (California Energy Commission), January 28, 2002.

NERC (North American Electric Reliability Council). 1999. 1994-1998 Generating Availability Report.